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EFFECT OF ADDITION OF COARSE SAND PARTICLES ON ENGINEERING PROPERTIES OF CLAY SOIL

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ABSTRACT

Expansive clay soils are known all around the world to be problematic due to its swelling and shrinking problem when wet and dry respectively. The project studies the effect of the addition of coarse sand particles on engineering properties of clay soil. Atterberg limit test and sieve particle size analysis were conducted on the clay soil to classify the clay soil in accordance to AASHTO soil classification system. The clay soil sample was simply classified as A-7-5 and sand particle as A-3 based on results from Atterberg limit test. Sand particles were added to clay soil at 5%, 10%, 15%, 20%, 25% and 30%. The following tests were conducted on the clay soil sample; compaction tests, Atterberg test and California bearing ratio (CBR). Compaction test had the following value; OMC of 12.1% at 0% of sand particles additives fell to lowest of 7.52% at 30% of sand particle additive, MDD of 17.1kN/m^3 at 0% and rose to 18.95kN/m^3. California bearing ratio test also shown an increase in CBR value. The following were the value gotten from the CBR test; CBR value of 6.63% at 0% of sand particles additive increased to 30.71% at 30% of sand particles additive.

KEYWORDS*: *OMC, MDD, CBR & Atterberg Limit Test

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Original Article

INTRODUCTION

Expansive clay soil has been sources of the problem to both highway and construction industries due to its swelling and shrinking problems. Although, there are mainly three general groups based on their crystalline arrangement namely Kaolinite, Montmorillonite and Illite groups, the one with higher expansive rate is those that belong to the montmorillonite group. There is only one factor that was responsible for this swelling and shrinking problems and that is the presence of clay minerals called montmorillonite and this mineral is scientifically called vertisol. Masoumeh & Masoud (2012) added other important minerals such as smectite, nontronite, vermiculite, illite, and chlorite. These minerals are responsible for high volume change property of clay soil. Many research works have studied the effect of expansive clay soils on structures such as foundation, highways, structural elements, architectural features etc. Expansion in clay soil may be informed of one of these two or both; Elastic re-bounces in the compressed soil mass and or Expansion in water sensitive clays due to ingress of free water. Verma & Maru (2013) and Masoumeh & Masoud (2012) explained further that factors that influenced swelling includes but not limited to the following; Soil properties which include clay mineralogy, soil water chemistry, soil suction, plasticity etc and environmental factors that includes Initial moisture content, moisture variation, climate, groundwater, drainage etc and finally stress conditions that includes stress history, in situ condition, loading, soil profile etc. The swell-shrink potential of expansive soils is determined by its initial water

content; void ratio; internal structure and vertical stresses, as well as the type and amount of clay minerals in the soil. Swelling and shrinkage are not fully reversible processes. The process of shrinkage causes cracks, which on re-wetting, do not close-up perfectly and hence cause the soil to bulk-out slightly, and also allow enhanced access to water for the swelling process (David, (1998), Masoumeh & Masoud (2012) and Verma & Maru (2013)). Fredlund (1975) and Masoumeh & Masoud (2012) explained further swelling pressures can cause heaving or lifting of structures whilst shrinkage can cause differential settlement. Failure results when the volume changes are unevenly distributed beneath the foundation. This behaviour leads to the prediction on most likely these expansive clay soils might behave. Robert & Gordon (1970) predicted that vertical swell both in one and two-dimensional soil regions in expansive clay soil and concluded that factors such as change of moisture content, together with the overburden, surcharge pressure at a point, total specific volume, specific water volume relationship for the soil at that point to predict a local change of volume are used in predicting heave and uplifting of expansive clay soils. Prediction of volume change behavior of unsaturated swelling soil is due to changes in stress conditions (Fredlund, 1983).

David (1998) documented the presence of expansive clay soils virtually in all continents of the world. Expansive soils are mostly found in the arid and semi-arid regions and it covers a large area of the world. It covers nearly 20% of the landmass in India and includes almost the entire Deccan plateau (Verma & Maru, 2013) and (Gandhi, 2012). Robert (2009) also cited the existence of expansive clay soils both in United Kingdom (UK) and United States (US) and quoted amounts of millions that have been spent due to problems caused by expansive clay soils. There is a vast deposit of clay spreads across every region in Nigeria, though their properties differ from site to site on account of geological differences (Kefas et al, 2007).

To control this swelling-shrinking behavior or improving engineering properties of these expansive clay soils, many methods has been suggested which includes replacing existing expansive soil with non-expansive soil, maintain constant moisture content and improve the expansive soils by stabilization (Masoumeh & Masoud, 2012). This report considered the later method of soil stabilization. Stabilization is the method or technique used in improving the quality or engineering properties of a soil material to meet construction requirement. Many methods has been used to stabilize soil and these include mechanical (or granular) stabilization, Bituminous stabilization, Thermal stabilization and Chemical stabilization which include use of lime, fly ash, calcium chloride, sodium chloride, sodium silicate and of recent pozzolanic materials from waste agricultural materials such Rice husk ash (RHA), groundnut shell ash (GSA), palm kernel shell ash (PKSA), bagasse ash, etc.

Koteswara et al (2012) did the extensive study on how rice husk ash, lime, and gypsum can be used to stabilize expansive soil and came to term that after rice husk ash, lime, and gypsum were added to the expansive clay soil which resulted in considerable improvement in the strength characteristic of the expansive clay soil. Gandhi (2012) studied how expansive clay soil can be stabilized using bagasse ash, he concluded that strength of the expansive clay soil was improved upon, stability was also increased and there was a decrease in swelling properties of the soil. Julius (2011) also successfully stabilized expansive clay soil with cane molasses. Chittaranjan et al (2011) used a various form of agricultural wastes such as rice husk ash (RHA), Sugarcane bagasse ash (SGBA) and groundnut shell ash (GSA) as the stabilizer and concluded that they added value to weak soils (such as black cotton soil) as a stabilizer. Laxmikant et al (2011) compared use of fly ash and rice husk ash as soil stabilizer for black cotton soil and concluded that both are of benefit to the black cotton soil but fly ash is a better soil stabilizer than rice husk ash. Oriola & Moses (2010) attempted to stabilize a black cotton soil

with groundnut shell ash and come to the conclusion that stabilization of black cotton soil with groundnut shell ash is unattainable but it shows progressive strength development. Fidelis & Ugochukwu (2009) studied the effect of rice husk ash on some geotechnical properties of lateritic soil and concluded that rice husk ash reduces plasticity, increased volume stability as well as the strength of the soil and concluded that 10% to be optimum content for stabilizing effect on lateritic soil. Brooks (2009) studied how to fly ash, rice husk ash can be used to stabilize an expansive clay soil and concluded that both rice husk ash and fly ash proved to be of benefit to the soil both in strength and swelling reduction development. Alhassan (2008) has also stabilized lateritic soil with rice husk ash and suggested 6-8% would be of benefit to the poor lateritic soil. Mohd Noor et al (1993) also studied the effect of cement - rice husk ash mixtures on compaction, strength, and durability of meleka series lateritic soil concluded that cement-rice husk ash admixture can be used to stabilize lateritic soil and also achieved desire durability characteristic recommended.

METHODS AND MATERIALS

Clay soil was collected after going 1.5m deep from a place known for its expansive clay soil, Otu in Itesiwaju Local government area in Oyo state. Nigeria. The sand particles were collected from nearby topsoil surface around in Ladoke Akintola University of Technology (LAUTECH), Ogbomosho, Oyo State. Nigeria. The properties of both clay and sandy soil particles are as shown in table 1.

The laboratory tests carried out include particle size distribution, Atterberg limit test, compaction test and California bearing ratio (CBR), they were all carried out in accordance with BS 1377 (1990) from British Standard Institute. The geotechnical properties of the clay soil were determined by carried out these tests with the addition of sand particles at the rate of 5% from 0% to 30%.

All compaction tests were carried out using Standard Proctor compaction energy in accordance with British Standard procedures. These helped to determine Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of each additive of sand soil particle. This involved energy derived from a hammer of 2.5 kg mass falling through a height of 30 cm in a 1000 cm^3 mold. The soil was compacted in three layers, each layer receiving 27 blows. The California bearing ratio (CBR) compaction involved the same hammer weight and drop height with each layer receiving 62 blows in a 2360 cm^3 mold.

RESULTS AND DISCUSSIONS

The preliminary geotechnical index properties of the clay soil before addition of sand soil particle and sand soil particle are as shown in Table 1. Soil classification of the clay soil and sand soil particles were done in accordance with the AASHTO soil classification system. Clay soil is classified as A-7-5 and sand soil particle is classified as A-3. Although, clay soil classification shows that is a weak soil with very poor drainage characteristic and general rating as subgrade that shows it has fair to poor properties as a subgrade and volume change is extremely high. Sand soil particle shows that it has excellent properties has subgrade in regards with its drainage character as well as general rating as subgrade and volume change is non-existence.

Effect of Addition of Sand Soil Particles

Compaction Characteristics

Compaction is the process of densification of the soil by reducing the air voids in the soil. It is aimed at establishing the soil's Optimum moisture content and Maximum dry density (Craig,1992). The dynamic compaction of soil samples was carried out to determine the maximum dry density (MDD) and Optimum Moisture Content (OMC) of the soil samples. Table 2 and figure 1 showed an increase in the value of MDD from $17.1KN/m^3$ at 0% to $18.95\ KN/m^3$ at 30%. Principally, increase in Maximum Dry Density (MDD) is an indicator of Improvement. Edeh, et al (2012) and David (1998) stated that materials with high MDD at relatively low moisture content are indicative of good soil materials. From the same table 2 and figure 1, OMC kept falling, from 12.1% at 0% to 7.52% at 30%. Principally, a decrease in Optimum Moisture Content (OMC) is an indicator of improvement. For good soil, the lower the OMC, the better is workability (Lambe & Whitman, 1969). David (1998) stated that a soil is considered to be stabilized when its OMC is lowered. It can be clearly seen that Optimum Moisture Content increase with the decrease in Maximum Dry Density and vice-versa (Rahman, 1987).

The reason for these increments in MDD and decrease in OMC areas results of higher specific gravity of sand soil particle than clay soil and it could also be as results of the lighter weight of clay soil compare to that of sand soil particle.

Table 1: Properties of the Natural Soil of both Clay Soil and Sand Soil Particles

	Clay soil	Sand soil
Natural Moisture Contents (%)	21.32	9.52
Liquid limit, LL (%)	64	−
Plastic limit, PL (%)	48	−
Plastic Index, PI (%)	16	NP*
Percent passing sieve No. 200	63	7
AASHTO soil classification	A-7-5	A-3
CBR- Unsoaked	6.63	−

NP mean non-plastic

California Bearing Ratio Characteristics

As an indicator of compacted soil strength and bearing capacity, it is widely used in the design of the base and sub-base material for pavement. It is also one of the common tests used to evaluate the strength of stabilized soils (Amu & Salami, 2010) and (Alhassan, 2008).

From table 3 and figure 2, it can be deduced that a percentage of sand soil particles additives increases, so is the CBR value increases. From 0% to 30% additives of sand soil particles, the CBR value also increased from 6.63% to 30.71%. The reasons behind it is that sandy soil has more bearing strength than clay soil and so is the shear strength of the sand soil particle compare to that of clay soil.

The table 2 below also showed the effect of the addition of sand soil particle on both the maximum dry density (MDD) and Optimum moisture content (OMC).

Table 2: Showing the Results of Sand Soil Particle Additives and its Effect on OMC and MDD

% of Sand Soil Particle Additives	OMC (%)	MDD in KN/m3
0	12.1	17.1
5	11.9	17.25
10	11.85	17.88
15	11.4	18.1
20	11.2	18.4
25	8.52	18.82
30	7.52	18.95

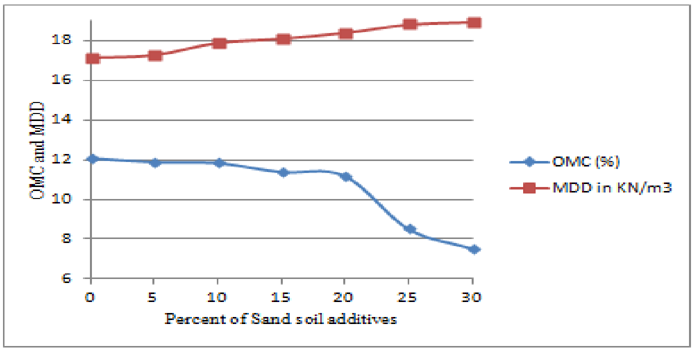

Figure 1: Showing the Graph of % Additives of Sand Soil Particle against MDD and OMC

Table 3: Showing the Results of sand Soil Particle Additives Against California Bearing Ratio (CBR)

% of Sand Soil Particle Additives	CBR (%)
0	6.63
5	15.12
10	16.33
15	20.77
20	21.43
25	26.13
30	30.71

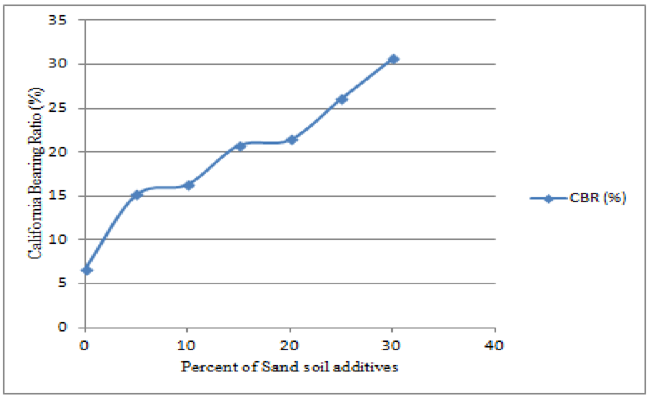

Figure 2: Percent of Sand Soil Particle against California Bearing Ratio (CBR)

CONCLUSIONS

From the results above, the following conclusions can be drawn about the laboratory study of the clay soil stabilized with sand soil particle.

- Both clay soil and sand soil particle can be classified as A-7-5 and A-3 respectively in accordance with the AASHTO soil classification system.
- Addition of sand soil particle increased the MDD and reduced the OMC i.e. Compaction of the clay soil stabilized with sand soil particle.
- Addition of sand soil particle increased the strength and bearing capacity i.e. CBR of clay soil stabilized with sand soil particle.
- From this laboratory investigation, it would appear that sand soil particle performs satisfactorily as a cheap stabilizing agent for clay soil.

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